EOS VOLUME 94 NUMBER 25 18 JUNE 2013

# Forum

cont. from page 224

cutting-edge technology and scientific expertise and excellence to make the case for science funding to maintain our nation's status as a world leader in the geosciences. Our foreign competition is catching up and in some cases has already surpassed us, weather forecasting models in Europe being a good example. Consider China, Brazil, and India, all of which are significantly increasing their investment in at-sea, atmospheric, Earth, and land-based laboratory infrastructure and human capital. China is building two 7000-meter human-occupied submersibles, and all three countries are constructing several large research vessels.

Given the immense fiscal, political, and scientific challenges facing the geosciences, we have to learn how to work together better as an Earth systems science community rather than a group of individual independent organizations. We also need to exercise "appetite control" by demonstrating an ability to set realistic priorities through decadal planning exercises. Our current model of doing business has to change because the budget constraints we are facing will not go away any time soon. Thus, the situation we are in is a dramatic sea change from budget scenarios of the past, and it is highly unlikely that we will go back to the way things were during the Cold War, when anti-submarine warfare

and the need for new innovative weapons systems such as advanced satellite technology drove the nation's research agenda. Our ability to conduct science in such an environment requires a paradigm shift in how we operate.

## Finding the Best Opportunities

Despite the extraordinarily challenging funding situations we face as scientists, I am an optimist. I believe that if you have a glass-half-full attitude in life rather than a glass-half-empty view, you will not spend your life thirsty. I also suggest to you that in chaotic and depressing times, there is opportunity if we are willing to change. While others are wringing their hands, those who accept and embrace change move forward and succeed. The decision is ours, and we need to make it now.

### References

Mervis, J. (2013), Proposed change in awarding grants at NSF spurs partisan sniping, *Science*, *340*(6133), 670, doi:10.1126/science.340.6133.670. Prewitt, K. (2013), Is any science safe?, *Science*, *340*(6132), 525, doi:10.1126/science.1239180.

—ROBERT B. GAGOSIAN, Consortium for Ocean Leadership, Washington D. C.; E-mail: rgagosian@ oceanleadership.org

# Swiss Re In these turbulent times, who knows what opportunities may blow your way? Chas in the Eurozone Global lactification confidence. Uncertainty Unrest. In such a vertail technomic climate, many people's first instinct is to run for shelter. But what if that meant missing out on fresh possibilities? At Swiss Re, confronting uncertainty has been our business for 150 years. And now, in today's ever more rapidly shifting risk landscape, our task is to be ever more agile and alert. We're here to identify emerging risks and opportunities alike, and enable our clients and brokers to look beyond the immediate challenges. At Swiss Re, risk is our raw material; what we create is opportunity. See which way the wind is blowing at www.swissre.com

# Economic Growth in the Face of Weather and Climate Extremes: A Call for Better Data

The U.S. economy has grown to be the world's largest, even in the face of the most varied and costly weather and climate extremes on the planet (see http://www.munichreamerica.com/webinars/2013\_01\_natcatreview/MunichRe\_III\_NatCat01032013.pdf). Nevertheless, these extremes continue to take a toll on the nation, diverting public and private funds while limiting economic growth and jobs and threatening the well-being of Americans. Extreme weather events affect every state and manifest differently by region (see Figure 1 in Supporting Information in the online version of this Forum and http://www.ncdc.noaa.gov/billions/summary-stats).

The United States is not alone in its vulnerability to weather and climate extremes. A recent Intergovernmental Panel on Climate Change (IPCC) assessment found that the impacts of extreme weather, climate, and geophysical events have increased globally [IPCC, 2012].

While adaptation, preparedness, and improved forecasting have helped reduce impacts, weather and climate extremes are increasingly frequent (see Figure 2 in Supporting Information in the online version of this Forum and Karl and Katz [2012]) and apparently more costly [Karl et al., 2009; U.S. Climate Change Science Program, 2008]. The National Climatic Data Center (NCDC) reported a record number of billion-dollar weather and climate disasters in 2011, at 14, with 2012 close behind, at 11 (see http://www.ncdc.noaa.gov/extremes, and http://www.ncdc.noaa.gov/sotc/national/2012/13).

Even as scientific understanding of the economic consequences of these extreme events improves, the nation lacks the data necessary to comprehensively understand their economic costs across years, events, and places. We are limited in our ability to accurately assess the changes in magnitude and composition of event costs, to more skillfully attribute the causes of changes in the costs of weather and climate extremes, and to state with confidence when and how policies intended to limit these impacts are working.

Our ability to attribute the causes of the increasing costs of weather and climate

extremes and the success of policy is diminished by the fact that long-term data on economic damages from extreme weather and climate events are neither complete nor consistent across federal agencies and the private sector [Smith and Katz, 2013]. No central federal authority consistently collects all relevant data and tracks the economic impacts. The private sector collects data on insured losses that result from weather and climate extremes but has not created a public domain data set and analysis framework that is sufficient for understanding the broader economic impacts. It has, however, collaborated closely with federal entities to provide data for special uses.

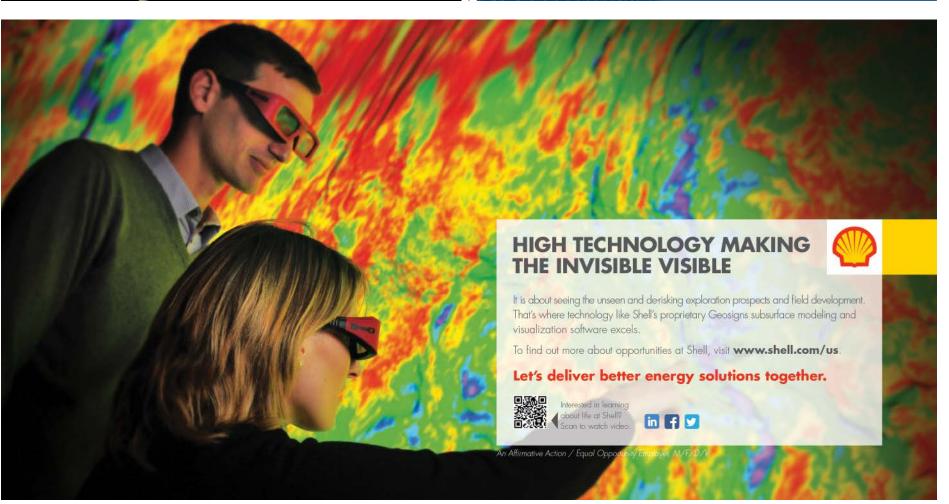
By comparison, the weather and climate community has a long history with a global monitoring network that is used to detect changes in weather and climate extremes, but by no means is it adequate [Trenberth et al., 2011]. For example, there are no data sets (with confidence intervals) for tracking changes in critical extreme events such as severe local weather (e.g., tornadoes, hail, and damaging winds). For other phenomena (e.g., hurricane intensity), error estimates for some regions are often wide and uncertain [Karl et al., 2009; IPCC, 2007]. Well-calibrated, unbiased data are required to explain the causes and costs of changes in these events; better observations lead to more confidence [Vose et al., 2013; Peterson et al., 2013]. The outlook for consistent observations for a variety of extremes is still challenging for both in situ [Global Climate Observing System (GCOS), 2003] and satellite observing systems [GCOS, 2010; National Research Council, 2008].

Current Systems for Collecting Data

The private sector collects data on certain economic impacts associated with U.S. weather events and hazards. Insured loss estimates are compiled by Property Claim Services (PCS). Uninsured losses are estimated by various means, often roughly expressed as a multiple of direct insurance losses. The PCS data include only those

Forum cont. on page 226





# Forum

cont. from page 225

with aggregate claims larger than \$25 million per event. Aggregate national-level data on insured and uninsured losses or life and health losses caused by weather and climate extremes are not usually accounted for in published loss estimates.

A patchwork of data on the economic impacts of extreme weather and climate events is collected by several federal agencies, each with different interests, roles, and constituencies that vary by sector, geography, and demographics. The U.S. Department of Agriculture (USDA) estimates reduced crop revenues and associated publicly insured losses. The Federal **Emergency Management Agency collects** data on publicly insured flood losses, limited to homes and small businesses. The National Oceanic and Atmospheric Administration's (NOAA's) National Weather Service (NWS) regularly reports the costs of local weather events. NOAA's National Hurricane Center relies on PCS estimates of hurricane losses.

Federal data collection is uniformly bottom-up; agencies compile data from disparate local sources. USDA collects data from county-level agriculture agents. NWS compiles data on weather impacts from forecasters at the nation's 122 weather forecasting offices. Across all of these institutions, there is no consistent methodology

or standard for rigor and peer review. The Government Accountability Office has performed some valuable reviews of these data but not an integrated assessment [Government Accountability Office, 2013].

All of these entities work largely independently—a fact that has led to different impact estimates (sometimes by design) for the same events [Smith and Katz, 2013]. For example, in September 2008, Hurricane Ike caused widespread losses along the Texas coast and farther inland, including severe gasoline shortages in the southeast states due to damaged oil platforms and infrastructure. The final PCS insurance payout estimate for Ike was about \$12.5 billion, while the National Flood Insurance Program payout was about \$2.5 billion [Smith and Katz, 2013].

The National Research Council recently released a report on natural disaster socio-economic impacts, including weather and climate extremes, and recommends risk-based approaches to resiliency that require improved data, modeling, and response for natural disaster anticipation [National Research Council, 2012].

Toward a Federal Accounting of Economic Impacts of Extreme Weather and Climate

The federal government plays a pivotal role as risk manager and insurer of last

resort for many types of climate and weather damages. Yet the federal government does not have the data needed to definitively answer key questions regarding the root causes of weather and climate extremes and resulting economic damages. This affects our ability to assess the effectiveness of policies designed to minimize these damages.

The only coordinated public sector effort to unify the existing mix of data from public and federal sources on the economic impacts of weather and climate extremes in the United States has been through NOAA's NCDC. However, NCDC has no standing or authority to encourage or impose methodological standards on other agencies or to promote improved data comparability.

The nation—indeed, the world—would benefit from a new approach to guarantee the rigor, reliability, comparability, and usefulness to science and policy of data on the economic impacts of extreme events and all natural hazards. Needed is a body that can provide public and private leadership, create and implement data collection and analysis standards, promote free and open data exchange, and report in an effective and unbiased way to the American public and decision makers the impact of weather and hazards on our economy and societal well-being.

The body should be nonpartisan and must combine the best federal, academic, and private sector knowledge and analytical techniques. It should possess excellent skills in risk communications. The body also should work with public and private partners to ensure proper stewardship and public access.

Because weather and natural disasters are ubiquitous, often with cross-border effects, a similar effort should be considered at a global level (see http://www.irdrinternational.org/about-irdr/scientific-committee/working-group/disaster-loss-data/). Without accurate and reliable data on the impacts of these events, our ability to manage and grow the economy will only worsen, in turn, compounding climate risk and placing more costs on government.

# Acknowledgments

We acknowledge the contributions of Adam Smith, Neal Lott, and James McMahon of NOAA's NCDC and the participants of NCDC's May 2012 Workshop on Billion Dollar Weather Damages.

# References

Global Climate Observing System (GCOS) (2003), The second report on the adequacy of the Global Observing Systems for Climate in support of the UNFCCC, *Rep. GCOS-82*, 74 pp., World Meteorol. Organ., Geneva, Switzerland. [Available at http://www.wmo.int/pages/prog/gcos/Publications/gcos-82\_2AR.pdf.]

Global Climate Observing System (GCOS) (2010), Implementation plan for the Global Observing System for Climate in support of the UNFCCC (2010 update), *Rep. GCOS-138*, 180 pp., World Meteorol. Organ., Geneva, Switzerland. [Available at http://www.wmo.int/pages/prog/gcos/ Publications/gcos-138.pdf.]

Government Accountability Office (2013), Highrisk series: An update, *Rep. GAO-13-283*, Washington, D. C.

Intergovernmental Panel on Climate Change (IPCC) (2007), Climate Change 2007: The Physical Science Basis—Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, edited by S. Solomon et al., 996 pp., Cambridge Univ. Press, Cambridge, U. K.

Intergovernmental Panel on Climate Change (IPCC) (2012), Summary for policymakers, in Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation: A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change, edited by C. B. Field et al., pp. 1–19, Cambridge Univ. Press, Cambridge, U. K.

Karl, T. R., and R. W. Katz (2012), A new face for climate dice, *Proc. Natl. Acad. Sci. U. S. A.*, 109(37), 14,720–14,721, doi:10.1073/pnas.1211721109.

Karl, T. R., J. M. Melillo, and T. C. Peterson (Eds.) (2009), Global Climate Change Impacts in the United States, 188 pp., Cambridge Univ. Press, Cambridge, U. K.

National Research Council (2008), Ensuring the Climate Record From the NPOESS and GOES-R Spacecraft: Elements of a Strategy to Recover Measurement Capabilities Lost in Program Restructuring, 190 pp., Natl. Acad. Press, Washington, D. C. National Research Council (2012), Disaster Resilience: A National Imperative, Natl. Acad. Press,

Peterson, T. C., et al. (2013), Monitoring and understanding changes in heatwaves, coldwaves, floods, and droughts in the United States: State of knowledge, *Bull. Am. Meteorol. Soc.*, doi:10.1175/BAMS-D-12-00066.1, in press.

Smith, A. B., and R. W. Katz (2013), US billiondollar weather and climate disasters: Data sources, trends, accuracy and biases, *Nat. Hazards, 67,* 387–410, doi:10.1007/s11069-013-0566-5.

Trenberth, K. E., A. Belward, O. Brown, E. Haberman, T. R. Karl, S. Running, B. Ryan, M. Tanner, and B. Wielicki (2011), Challenges of a sustained climate observing system, paper presented at Open Science Conference, World Clim. Res. Program, Denver, Colo. [Available at http://www.wcrp-climate.org/conference2011/documents/Trenberth.pdf.]

U.S. Climate Change Science Program (2008), Weather and Climate Extremes in a Changing Climate—Regions of Focus: North America, Hawaii, Caribbean, and U.S. Pacific Islands, edited by T. R. Karl et al., 164 pp., Washington, D. C. Vose, R. S., et al. (2013), Monitoring and understanding changes in extremes: Extratropical storms, winds and waves, Bull. Am. Meteorol.

—LINWOOD PENDLETON, National Oceanic and Atmospheric Administration (NOAA) and Nicholas Institute for Environmental Policy Solutions, Duke University, Durham, N. C.; THOMAS R. KARL, National Climatic Data Center, NOAA, Asheville, N. C.; E-mail: Thomas.R.Karl@noaa.gov; and EVAN MILLS, Lawrence Berkeley National Laboratory, Berkeley, Calif.

# nature climate change submit online now!

Chief Editor: Rory Howlett, PhD Senior Editor: Monica Contestabile, PhD Associate Editor: Alastair Brown, PhD Associate Editor: Bronwyn Wake, PhD

Nature Climate Change aims to be the world's leading research journal for documenting new scientific discoveries about how we will experience and respond to the challenges of a changing climate.

The Editorial team accepts submissions of original research articles from both the natural and social science communities. Central to the journal's mission, and to addressing climate change, is reaching beyond traditional academic boundaries, and bringing together diverse expertise and perspectives. As such, *Nature Climate Change* especially encourages the submission of interdisciplinary climate research. In addition, the journal welcomes disciplinary research from psychology to sociology, from policy to atmospheric physics.

# Topics covered in the journal include:

- Adaptation
- AnthropologyAtmospheric science
- Biochemistry
- CommunicationCryospheric science
- Ecology
- Economics
- Geography
- Hydrology
- Impacts and vulnerabilityMitigation
- Modelling
- OceanographyPalaeoclimate
- Policy and governance
- PhilosophyPsychology
- Psychology
- SociologySustainability and development

# Submit today!

We welcome your contributions.

Go to: http://mts-nclim.nature.com/cgi-bin/main.ple

www.nature.com/natureclimatechange

nature publishing group npg





For more information go to:



# Predicting and Detecting Natural and Induced Flow Paths for Geothermal Fluids in Deep Sedimentary Basins

19–23 October 2013 Park City, Utah, USA

Application Deadline: 19 July 2013

# COSPONSORS:

**National Science Foundation** 

THE GEOLOGICAL SOCIETY OF AMERICA®

www.sedheat.org www.geosociety.org/penrose/13utah.htm

Renew Your Membership Today! membership.agu.org

# Growing the U.S. Economy in the Face of Weather and Climate Extremes: A Call for Better Data - Supplementary Material

Linwood Pendleton<sup>1</sup>, Thomas R. Karl<sup>2</sup>, and Evan Mills<sup>3,4</sup>

# **Figures**

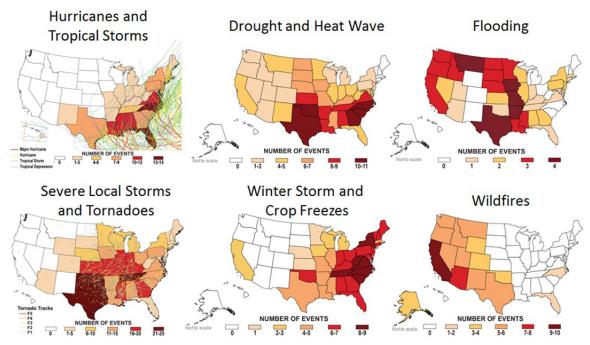


Figure 1.

Number of billion-dollar events (including CPI adjustment to 2012) by event category for the period 1980 – 2011. Costs of wide-area events are apportioned across states, and may not amount to \$1B of damage in each affected state. The 'Severe Local Storms and Tornadoes' map reflects billion-dollar events for combined tornado, hail and straight-line wind damage, and is overlaid by tornado-intensity tracks as one indicator of event distribution. The 'Hurricane and Tropical Storm' map is overlayed with storm tracks. Source: NOAA/NCDC.

<sup>&</sup>lt;sup>1</sup> Acting Chief Economist, NOAA and Director of Ocean and Coastal Policy, Duke's Nicholas Institute.

<sup>&</sup>lt;sup>2</sup> Director, National Climatic Data Center, NOAA

<sup>&</sup>lt;sup>3</sup> Staff Scientist, Lawrence Berkeley National Laboratory

<sup>&</sup>lt;sup>4</sup> We would like to acknowledge the contributions of Adam Smith, Neal Lott, and James McMahon of NOAA's NCDC and the participants of the May Workshop on Billion Dollar Weather Damages, held at NCDC in Asheville.

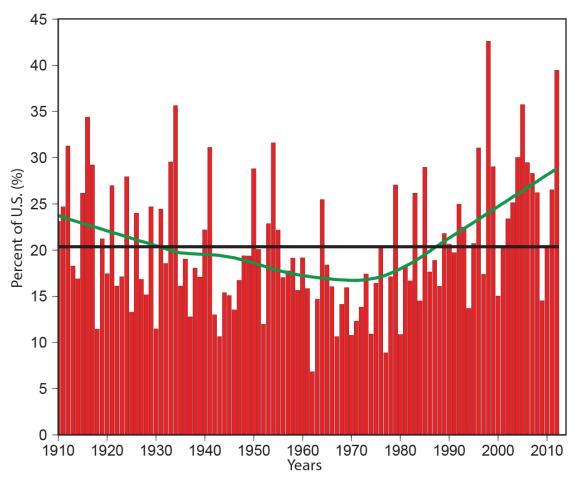


Figure 2.

Annual U.S. Climate Extremes Index 1910-2011. Red bars indicate the annual percentage of the continuous U.S. land area experiencing extreme conditions; black line is the average over entire period of record; green line shows a locally weighted linear regression method "Lowess" to indicate multidecadal changes using a smoothing span equal to 50% of the time series length. The index considers extremes in maximum and minimum temperature, soil moisture excess and deficits, extremes in 1-day precipitation; extremes in days with or without precipitation; and landfalling tropical storm and hurricane wind speed and duration. Based on change point and non-parametric tests of statistical significance, there is a significant (0.01) positive trend in the Index value since the late 1960's, but no overall significant trend since 1910, nor any significant decreasing trend from 1910 to the late 1960's. Several important extremes are not yet reflected in the index, including tornados and severe thunderstorm outbreaks, ice storms, and blizzards/snowstorms.<sup>iii</sup>

<sup>&</sup>lt;sup>1</sup> Lund, R., and J. Reeves, 2002: Detection of undocumented changepoints: A revision of the two-phase regression model, *J. Climate*, **15**, 2547–2554, doi:10.1175/1520-0442(2002)015<2547:DOUCAR>2.0.CO;2.

ii Helsel D.R., and Hirsch, R.M., 2002, Statistical methods in water resources—Hydrologic analysis and interpretation: Techniques of Water-Resources Investigations of the U.S. Geological Survey, chap. A3, book 4, 510 p.

iii Gleason, K.L., J.H. Lawrimore, D.H. Levinson, T.R. Karl, D.J. Karoly, 2008: A Revised U.S. Climate Extremes Index. *J. Climate*, **21**, 2124–2137. doi: http://dx.doi.org/10.1175/2007JCLI1883.1